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Quarterly Technical Summary

Advanced Electronic
Technology

15 May 1971

Prepared under Electronic Systems Division Contract F19628-70-C-0230 by

Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts



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INTRODUCTION

This Quarterly Technical Summary covers the period from 1 February through 30 April 1971. It consolidates the reports of Division 2 (Data Systems) and Division 8 (Solid State) on the Advanced Electronic Technology Program.

Accepted for the Air Force
Joseph R. Waterman, Lt. Col., USAF
Chief, Lincoln Laboratory Project Office

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DATA SYSTEMS DIVISION 2

INTRODUCTION

This section of the report reviews progress during the period 1 February through 30 April 1971 for the Advanced Electronic Technology Program of Division 2. Separate progress reports on Graphics, Propagation Studies, Seismic Discrimination and the Educational Technology Program describe other work in the Division.

**M. A. Herlin
Acting Head, Division 2**

DIGITAL COMPUTERS GROUP 23

I. INTEGRATED CIRCUIT DEVELOPMENT

Five wafers of deep diffused transistors have been completely processed through the four mask test patterns to produce working devices. Initial testing shows most parameters close to the desired values although there is evidence that some contamination has taken place. An additional ten wafers are being metallized with fifteen more at the base and emitter cut stages. Fabrication of shallow devices has started.

Problems with undercutting of the phosphorous glass layers have been solved for contact metallization by using two separate photoresist exposures for the cut. Problems with obtaining good aluminum adhesion, which were eliminated by depositing at 200°C, led to undesirable grain structure and unsatisfactory roughness for photoresist. Evaporation at room temperature provides smooth aluminum with poor, but adequate, adhesion for etching. After etching, the wafer is heat treated at 500°C to improve the adhesion for subsequent processing.

A metallization jig for aluminum evaporation has been fabricated. The most successful process tried for producing a homogeneous 98% Al 2% Si film, as required for metallization on shallow junction devices, has been fractionation from a 67% Si 33% Al alloy melt.

The first wafers with epitaxial layers purchased outside have been delivered. These N⁺ type substrates have a layer of epitaxial N material which will allow us to fabricate and measure high-frequency discrete transistors. Samples with N-type material on P substrates with the necessary buried collectors for integrated circuits are proving more difficult to procure from outside vendors.

II. PHOTOLITHOGRAPHIC INTERCONNECTION OF PLASTIC-IMBEDDED SEMICONDUCTOR CHIPS

Improvement in the adhesion of silane-coupled polyester to nickel has been obtained by substitution of a water-detergent spray in place of an alcohol/styrene spray for removal of unexposed resin in the vias of array dielectric layers. The latter technique, while effective for via clean-out, was found to degrade the bond of the resin to chip pads.

Optimization of parameters of the photoselective metal deposition process (PSMD - Western Electric Company) is progressing and is almost ready for making array wiring. This additive process deposits metal only where desired, thereby eliminating the need for photoresist and etching.

III. SEMICONDUCTOR TESTING

A. Non-Contact Integrated Circuit Current Probe

A jig has been designed and constructed for holding and partially masking the 0.5 mm diamond cube substrate during vacuum metallization of four of its surfaces. A holder for the diamond has also been designed and constructed. It will provide electrical and thermal contact to

Division 2

the diamond (on which the probe is fabricated) as well as mechanical support for positioning it over the integrated circuit being probed and optical viewing of the circuit through the diamond.

An attempt is being made to scale up the magnetoresistive magnetic field sensor used in the non-contact current probe to sense very small magnetic fields ($<10^{-6}$ Oe). Tests have shown that random noise in the electronic components can be kept small enough, but the problem of environmental magnetic fields (from electric motors, fluorescent light ballasts, moving shoe nails, etc.) will be more difficult.

B. Transistor Measurement Equipment

An operational amplifier power supply having an output voltage range of -100.0 to +100.0 V has been built for measuring breakdown voltages and leakage currents. An operational amplifier ammeter for measuring currents in the range of 1 pA to 10.0 mA is also being built. It will be used to measure leakage currents, breakdown currents and diode forward currents.

The transistor bias control unit has been breadboarded. It is being tested for accuracy and stability. The digital voltmeter control and digital-to-analog converters have been designed and are being fabricated.

Major modifications to the testing program are being made to meet requirements for additional device measurements.

IV. MACHINE DEVELOPMENT

A. LX-1 Microprocessor

The interfaces between LX-1 and other portions of the Terminal Support Processor (TSP) have been designed and built. The central processor control is now built and the in/out design has been completed. LX-1 will be checked out in the next quarter by connecting it to the display generator and using the SEL test computer to simulate the META 4 computer.

B. TX-2 Double Raster Display System

A high performance system for design of LSI (Large Scale Integration) masks is now in its final stages of hardware construction. The system uses a "double raster display," whose beam traces alternate horizontal and vertical raster patterns. The elementary constituents of the picture are horizontal and vertical lines 0.050 inch long. For a given capability of the deflection and intensification amplifiers, the detail that can be shown by this double raster method is an order of magnitude higher than by conventional raster displays and two orders of magnitude higher than by vector displays.

The system displays four superimposed sheets of information (corresponding to different IC mask levels) with the intensity of each sheet individually adjustable by front panel controls, and with perfect registration between sheets. A fast phosphor with an interlaced 50/sec frame rate (100/sec effective rate) is used so that the display can show fast continuous window motion and yet be completely flicker-free. The mask drawings to be displayed are stored as 1 bit/(0.050 inch segment)/sheet; the entire drawings are stored in the TX-2 drum, while the area actually displayed is duplicated in a 16K core memory continuously read by the display.

To help TX-2 in processing the large numbers of bits of the picture, a small computer (called C4) with specialized instructions was appended to the display. A new control for the TX-2 memory bus switch, enabling the double raster display and the C4 computer to access the TX-2 memories, was also constructed.

It is expected that the hardware part will be completed within the next quarter and that the entire system will be operative by the end of 1971.

C. Test Computer

The SEL810A Test Computer facility has been used to test approximately 125 plug-in units of approximately 20 different types for the LX-1 microprocessor. It is also being used to test and exercise the TSP serial communicator and is being prepared to exercise the LX-1 computer and display generator.

COMPUTER SYSTEMS
GROUP 28

A small change was made in the magnetic tape subsystem at the end of March with the release of one tape drive, one controller and one selector subchannel. The loss of the control unit and subchannel means that the number of independent paths from tape to memory is reduced from three to two. The apparent effect of this change has been negligible, but the reduction from fifteen to fourteen drives is more difficult to assess.

Offsetting software facilities involving tape drive use have been added to the CP/CMS time sharing system during the quarter. The first of these permits the average user to send output destined for the Stromberg Carlson 4060 CRT Plotter to intermediate disk storage instead of tape. Periodically the system operator collects all such output from disk and stacks it on a single tape to be run on the 4060. From several points of view this is a more efficient procedure and one which lessens the demand for individual tape drive assignments. However, almost concurrently, a new tape I/O facility with improved error recovery procedures was introduced. This, together with other small changes, is expected to increase the use of individual tapes under the Batch Monitor feature of CP/CMS. The net effect of these two modifications on total tape drive demand is under continuing study.

Among the new capabilities provided as a byproduct of the activity of interfacing to the ARPA network is support for virtual terminal device access to a virtual machine. More generally the network project has progressed to the point where CP/CMS programs on the Lincoln 360/67 have been able to log into the UCLA time-sharing system.

Work has been started on a later version of the OS/360 batch processing system and HASP peripheral coordinating program. Among the expected advantages will be the optional System Management Facilities (SMF). SMF generates data on the use of system resources and data sets. Such information should be of considerable value in tuning OS to peak performance or in designing better hardware and software configurations. The overhead cost of up to ten percent will have to be balanced against the value received. The additional core residence space required by SMF will be provided from area released by the new overlay structure of the later version of HASP.

SOLID STATE DIVISION 8

INTRODUCTION

This section summarizes the work of Division 8 from 1 February through 30 April 1971. A more detailed presentation is covered by the Solid State Research Report for the same period.

A. L. McWhorter
Head, Division 8

P. E. Tannenwald
Associate Head

DIVISION 8 REPORTS

ON ADVANCED ELECTRONIC TECHNOLOGY

15 February through 15 May 1971

PUBLISHED REPORTS

Journal Articles*

JA No.

3684	Growth of EuO, EuS, EuSe and EuTe Single Crystals	T. B. Reed R. E. Fahey	J. Crystal Growth <u>8</u> , 337 (1971)
3747	Electron Spin Waves in Non-magnetic Conductors: Self-Consistent-Field Theory	F. A. Blum	Phys. Rev. B <u>3</u> , 2258 (1971)
3748	Shubnikov-de Haas Measurements in $Pb_{1-x}Sn_xTe$	J. Melngailis T. C. Harman J. G. Mavroides J. O. Dimmock	Phys. Rev. B <u>3</u> , 370 (1971), DDC AD-721065
3758	Critical Magnetic Properties and Exchange Interactions in EuO	N. Menyuk K. Dwight T. B. Reed	Phys. Rev. B <u>3</u> , 1689 (1971)
3761	Conceptual Phase Diagram and Its Application to the Spontaneous Magnetism of Several Pyrites	J. B. Goodenough	J. Solid State Chem. <u>3</u> , 26 (1971)
3782	Type Conversion and n-p Junction Formation in $Hg_{1-x}Cd_xTe$ Produced by Proton Bombardment	A. G. Foyt T. C. Harman J. P. Donnelly	Appl. Phys. Letters <u>18</u> , 321 (1971)
3785	Rapid Scanning Microscope for Light Probing and Infrared Mapping	R. J. Phelan, Jr. [†] N. L. DeMeo, Jr.	Appl. Optics <u>10</u> , 858 (1971).
3788	Field-Dependent Central-Cell Corrections in GaAs by Laser Spectroscopy	H. R. Fetterman D. M. Larsen G. E. Stillman P. E. Tannenwald J. Waldman [†]	Phys. Rev. Letters <u>26</u> , 975 (1971)
3795	The Fermi Surface and Optical Properties of Potassium	G. Dresselhaus A. R. Wilson C-Y. Young	Solid State Commun. <u>8</u> , 2125 (1970)

* Reprints available.

[†] Author not at Lincoln Laboratory.

Division 8

JA No.

3804	Effects of Short-Range Interactions on Electron-Charge Ordering and Lattice Distortions in the Localized State	R. A. Bari	Phys. Rev. B <u>3</u> , 2662 (1971)
3812	Two-Magnon Raman Scattering and Exchange Interactions in Antiferromagnetic KNiF_3 and K_2NiF_4 and Ferrimagnetic RbNiF_3	S. R. Chinn H. J. Zeiger J. R. O'Connor	Phys. Rev. B <u>3</u> , 1709 (1971)
3813	n-p Junction Photovoltaic Detectors in PbTe Produced by Proton Bombardment	J. P. Donnelly T. C. Harman A. G. Foyt	Appl. Phys. Letters <u>18</u> , 259 (1971)
3831	Anomalously High "Mobility" in Semiconductors	C. M. Wolfe G. E. Stillman	Appl. Phys. Letters <u>18</u> , 205 (1971)
3850	Efficient, Single-Mode, cw, Tunable Spin-Flip Raman Laser	S. R. J. Brueck A. Mooradian	Appl. Phys. Letters <u>18</u> , 229 (1971)
3854	Laser Tests ICs with Light Touch	R. E. McMahon	Electronics <u>44</u> , 92 (1971)
3857	Observation of Nonextremal Fermi-Surface Orbita in Bulk Bismuth	V. E. Henrich	Phys. Rev. Letters <u>26</u> , 891 (1971)

MS No.

2891	Optical Properties of the Alkalies Using the KKR-Z Method	A. Wilson G. Dresselhaus C-Y. Young	<u>Computational Methods in Band Theory</u> , edited by P. M. Marcus, J. F. Janak and A. R. Williams (Plenum Press, New York, 1971); Proceedings Conference on Computational Methods in Band Theory, Yorktown Heights, New York, 14-15 May 1970
2951	Localized Versus Itinerant Electrons in Magnetic Solids	J. B. Goodenough	<u>Summer School on the Theory of Magnetism of Metals</u> , Zakopane, Poland, 31 August - 11 September 1970, Vol. 1 (Institute of Physics of the Polish Academy of Sciences, 1971), pp. 124-329
2959	Magnetic Properties of Europium: Pressure and Impurity Effects	N. Menyuk K. Dwight J. A. Kafalas	J. Appl. Phys. <u>42</u> , 1301 (1971)
2961	Effect of Pressure on the Magnetic Properties of $\text{Ca}_{1-x}\text{Sr}_x\text{MnO}_3$	J. A. Kafalas N. Menyuk K. Dwight J. M. Longo	J. Appl. Phys. <u>42</u> , 1497 (1971)

MS No.

2966	High Pressure RbFeCl ₃ - A Transparent Ferrimagnet	J. M. Longo J. A. Kafalas N. Menyuk K. Dwight	J. Appl. Phys. <u>42</u> , 1561 (1971)
2970	Magnetic Phase Transitions in EuTe	N. F. Oliveira, Jr.* S. Foner* Y. Shapira* T. B. Reed	J. Appl. Phys. <u>42</u> , 1783 (1971)

* * * *

UNPUBLISHED REPORTS

Journal ArticlesJA No.

3752A	A Raman Study of the Semiconductor-Metal Transition in Ti ₂ O ₃	A. Mooradian P. M. Raccah	Accepted by Phys. Rev. B
3791	Theory of Electron-Surface Plasmon Interactions in Tunneling, Low Energy Electron Diffraction and in Photoemission	K. L. Ngai E. N. Economou*	Accepted by Phys. Rev. B
3838	Far Infrared Mixing in High-Purity GaAs	B. Y. Lao M. M. Litvak	Accepted by J. Appl. Phys.
3847	Carrier Concentration and Mobility in n- and p-Type ZnTe-Al	F. T. J. Smith	Accepted by Solid State Commun.
3863	Raman Spectra and Lattice Dynamics of Tellurium	A. S. Pine G. Dresselhaus	Accepted by Phys. Rev. B
3867	Spin Wave Approach to Two-Magnon Raman Scattering in a Simple Antiferromagnet	R. W. Davies S. R. Chinn H. J. Zeiger	Accepted by Phys. Rev. B
3868	The Two Components of the Crystallographic Transition in VO ₂	J. B. Goodenough	Accepted by J. Solid State Chem.
3887	High Pressure Synthesis of (ABX ₃) _n Compounds	J. A. Kafalas J. M. Longo	Accepted by J. Solid State Chem.

* Author not at Lincoln Laboratory.

Division 8

Meeting Speeches*

MS No.

2757A	Metal-Semiconductor Contacts on $Pb_{1-x}Sn_xTe$	K. W. Nill	Seminar, U.S. Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland, 15 April 1971
2799C	Optical Study of the Semiconductor to Metal Transition in Ti_2O_3	P. M. Raccah	Seminar, New York University, 23 February 1971
2989A	Testing Integrated Circuits with a Laser Beam	R. E. McMahon	XVIII Congresso Scientifico Internazionale Per L'Electronica, Rome, Italy, 29-31 March 1971.
3001	High Apparent Mobility in Inhomogeneous Semiconductors	C. M. Wolfe G. E. Stillman J. A. Rossi	
3008	A Comparative Study of Liquid Solution Models for III-V and II-VI Binary Systems	J. M. Steininger R. F. Brebrick	139th National Meeting, The Electrochemical Society, Washington, D.C., 9-14 May 1971
3122	Crystal Growth and Properties of Semiconducting, Ferromagnetic $Fe_{1-x}Cu_xCr_2S_4$ Alloys	M. D. Banus A. J. Strauss	
3026	Transparent Gold Films for High Temperature Furnaces	T. B. Reed W. J. LaFleur	
3027	Multilayer Interconnections on Ceramic	F. J. Bachner H. H. Pichler	73rd Annual Meeting, American Ceramic Society, Chicago, 24-29 April 1971
3065	Semiconductor-to-Metal Transition in VO_2	J. B. Goodenough	
3032	Polaron Self-Energy Effects on Higher Landau Levels in InSb	E. J. Johnson K. L. Ngai	
3042	Non-extremal Fermi Surface Areas in Bismuth	V. E. Henrich	
3045	Optical Study of Spin-Flop in Cr_2O_3	J. W. Allen	American Physical Society Meeting, Cleveland, 29 March - 1 April 1971
3046	Phonon Dispersion Relations in Tellurium	G. Dresselhaus A. S. Pine	
3047	Galvanomagnetic Measurements at Hydrostatic Pressure on $Hg_{1-x}Cd_xTe$ Alloys Near the Semimetal-Semiconductor Transition	C. T. Elliott J. Melngailis T. C. Harman J. A. Kafalas	

* Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

MS No.

3048	Shubnikov-de Haas Measurements in $Pb_{1-x}Sn_xSe$	J. Melngailis T.C. Harman
3049	Capacitance-Voltage Measurements on InAs and PbTe Schottky Barriers: Effects of the Inverted Surfaces	K. W. Nill J.N. Walpole*
3050	Calorimetry, Normal Incidence Optical Spectra and Magnetic Properties of the $NiS_{(1-x)}Se_x$ System Across the Semiconductor-to-Metallic Transition	P. M. Raccah J.B. Goodenough
3051	Absolute Experimental X-Ray Form Factor of Copper	R. J. Temkin V.E. Henrich P. M. Raccah
3056	Lattice and Correlation Effects on Narrow-Band Electrons	R. A. Bari
3057	How Hydrogenic are Shallow Donors in GaAs?	R.C. Brandt G.E. Stillman D.M. Larsen C.M. Wolfe
3058	Efficient, Single Mode, CW, Tunable Spin-Flip Raman Laser	S. R. J. Brueck A. Mooradian
3059	Effect of Hydrostatic Pressure on Electrical Properties of n-Type CdTe	G.W. Iseler J.A. Kafalas A.J. Strauss
3061	Multielectron Field Emission	K. L. Ngai R. A. Bari
3062	Interband Magnetoreflection of $Hg_xCd_{1-x}Te$	C. R. Pidgeon* T. C. Harman S. H. Groves
3063	Kinetics of Electron Transfer in n-Type CdTe	A. J. Strauss G. W. Iseler J. A. Kafalas
3066	Lineshapes of Spontaneous Spin-Flip Light Scattering in Semiconductors	F. A. Blum S. R. J. Brueck

American Physical Society Meeting,
Cleveland, 29 March - 1 April 1971

* Author not at Lincoln Laboratory.

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<u>MS No.</u>			
3043B, 3043C, 3043D	Semiconductor-to-Metal Transitions	J. B. Goodenough	Colloquium, The University of Manitoba, Winnipeg, Canada, 9 March 1971; Solid State Seminar, University of California, Berkeley, 10 March 1971; Solid State Science and Engineering Colloquia, Columbia University, 24 March 1971
3051A	Absolute Experimental X-Ray Form Factor of Copper	R. J. Temkin	Solid State Physics Seminar, Purdue University, 19 April 1971
3060A	Laser Magneto-Spectroscopy of Field Dependent Central Cell Corrections in GaAs Donors	H. R. Fetterman D. M. Larsen J. Waldman*	
3082	Acoustical Activity and Shear Wave Dispersion in Quartz	A. S. Pine	
3086	Magnetic Phase Transition and Self-Consistent Magnetic Induc- tion in Itinerant Antiferro- magnetism	C-Y. Young J. W. Allen	American Physical Society Meeting, Washington, D.C., 26-29 April 1971
3093	Paramagnetic Resonance in Fer- rous Fluosilicate at Submilli- meter Wavelengths	R. S. Rubins* H. R. Fetterman	
3067	Polaron Morphologies in Vanadium Oxides	J. B. Goodenough	International Conference on Con- duction in Low Mobility Materials, Eilat, Israel, 5-8 April 1971
3077	Type Conversion and N-P Junc- tion Formation in $Hg_{1-x}Cd_xTe$ Produced by Proton Bombardment	A. G. Foyt T. C. Harman J. P. Donnelly	
3078	N-P Junction Photovoltaic Detec- tors in PbTe and $Pb_{1-x}Sn_xTe$ Pro- duced by Proton Bombardment	J. P. Donnelly T. C. Harman A. G. Foyt	
3079	Development of N-P Junction Photovoltaic Detectors in InSb Fabricated Using Proton Bombardment	A. G. Foyt W. T. Lindley J. P. Donnelly	IRIS Detector Specialty Group Meet- ing, San Diego, 17-18 March 1971
3080	High Speed $Hg_{1-x}Cd_xTe$ Photodiodes	I. Melngailis T. C. Harman E. D. Hinkley W. T. Lindley	
3091A, 3091B	Optical Properties of the Alkalies Using the KKR-Z Method	C-Y. Young	Physics Seminar, Northeastern University, 3 March 1971; Univer- sity of Massachusetts, Boston, 9 April 1971

* Author not at Lincoln Laboratory.

MS No.

3095, 3095A	Lattice Distortions and Mott Insulators	R. A. Bari	Physics Seminar, Northeastern University, 24 February 1971; New York University, 1 March 1971
3102	Some Comparisons of Oxides and Fluorides of the Transition Elements	J. B. Goodenough	Conference on New Fluorides and Their Physical Properties, Montpellier, France, 2 April 1971
3106	Empirical Regularities in Ex- change Processes	J. B. Goodenough	Conference on Exchange Interactions Between Ions in Crystals and Mol- ecules, Princeton University, 12-14 May 1971
3112	Stimulated and Spontaneous Spin- Flip Raman Scattering in InSb	S. R. J. Brueck	Seminar, M.I.T., 22 March 1971
3123	Introduction to Nonlinear Optics	P. L. Kelley	Spring Meeting, New England Sec- tion, American Physical Society, Amherst College, 2-3 April 1971
3133	Lattice Dynamics and Light Scattering in Optically Active Crystals	G. Dresselhaus	Physics Seminar, Purdue University, 23 April 1971
3134	Infrared Photodiodes Fabricated by Proton Bombardment	J. O. Dimmock A. G. Foyt J. P. Donnelly T. C. Harman W. T. Lindley	11th Midcourse Measurements Meeting, San Bernardino, California, 20 April 1971

SOLID STATE DIVISION 8

I. SOLID STATE DEVICE RESEARCH

Progress has been made in improving the performance of InSb photodiodes and photodiode arrays fabricated by proton bombardment. Through the development of new surface coating and passivating techniques, the 77° K reduced background peak detectivities of these photodiodes at 4.8 μm have been increased from 3 to $5 \times 10^{11} \text{ cm Hz}^{1/2}/\text{W}$ to $1.1 \times 10^{12} \text{ cm Hz}^{1/2}/\text{W}$. In addition planar, uniform, multielement arrays of InSb photodiodes have been fabricated in which all elements are high sensitivity active devices.

CW, tunable, diode lasers of $\text{PbS}_{1-x}\text{Se}_x$ have been fabricated with output in the wavelength region near 5 μm . The variation of emission wavelength with composition, temperature, magnetic field and current through the diode was obtained. CW power of 8 μW at 12° K from a tunable $\text{PbS}_{0.82}\text{Se}_{0.18}$ diode laser emitting at 4.74 μm with an estimated linewidth of 1 MHz was measured at one end of the cavity. The doppler linewidth and doppler limited absorption coefficient at room temperature of the P(9) fundamental absorption line of CO at 2107.4 cm^{-1} were determined by tuning the laser line with current through the absorption line.

Preliminary results have been obtained on the epitaxial growth of $\text{In}_x\text{Ga}_{1-x}\text{As}$ alloys of low indium composition using an $\text{In}-\text{Ga}-\text{AsCl}_3-\text{H}_2$ open tube flow system. Single crystal n-type alloy layers 41 to 83 μm thick were obtained with energy gaps between 1.28 and 1.25 eV (vs 1.41 for GaAs), carrier concentrations between 1.4 and $9.2 \times 10^{14} \text{ cm}^{-3}$ and room temperature mobilities between 5500 and 7100 $\text{cm}^2/\text{V-sec}$. Mobilities at 77° K as high as 72,000 $\text{cm}^2/\text{V-sec}$ have been obtained.

GaAs Schottky barrier mixer diodes suitable for 50 GHz mixers have been fabricated using a technique designed to minimize parasitic parallel capacitances, series resistance and series inductance. The fabrication is accomplished in two distinct series of steps dealing with the two sides of a GaAs layer, and results in active devices formed on pockets of GaAs about 2 μm thick and 1 by 3 mils in area. Measurements made at low frequencies indicate that the diodes have zero-bias capacitances of 0.02 to 0.03 pF and impedances of 30 to 50 ohms.

270 MHz acoustic surface wave delay lines with 5 MHz bandwidth and a delay of 1.8 μsec have been fabricated on (100) surface semi-insulating GaAs (aligned along the [011] axis). Using double stub tuners the insertion loss was reduced to 15 dB, most of which was due to the electrical mismatch between the 50-ohm RF generator and the 5-ohm impedance of the transducers. Measurements on longer (3.6 μsec) delay lines indicate that the propagation losses for this cut of GaAs are less than 0.5 dB/ μsec at 270 MHz.

A program has been undertaken to develop a process utilizing X-radiation to replicate extremely high resolution microelectronic patterns. These submicron structures will be written with a scanning electron microscope into specially designed X-ray pattern masks. Such patterns can then be reproduced an unlimited number of times since the large spacing between the mask and wafer, allowable with X-rays, greatly reduces the chance of damage to the pattern mask.

II. MATERIALS RESEARCH

The insulating properties of embossed tantalum sheet (in the form of multiple heat shields) and stabilized zirconia felt have been tested up to 2550° and 2300° C, respectively. These are promising materials for use in insulating high temperature furnaces because of the convenience with which they can be fabricated into the required forms.

A new compound with perovskite structure, BiRhO_3 , has been prepared by high-pressure synthesis. The compound is formed when a stoichiometric mixture of Bi_2O_3 and Rh_2O_3 is placed in a platinum capsule and subjected to a pressure of over 65 kbar at 1000° to 1300° C for one-half hour.

Whereas VO_2 has a single monoclinic-to-tetragonal phase transformation at a semiconductor-to-metal transition, several $\text{V}_{1-x}\text{M}_x\text{O}_2$ systems exhibit two crystallographic changes: monoclinic-to-orthohombic at T_t' and orthorhombic-to-tetragonal at T_t . We point out that there are two components to the deformation to monoclinic symmetry: an antiferroelectric displacement of the cations and the formation of V-V homopolar-bonded pairs. Changes in T_t and T_t' with x and the cation M can be accounted for by a model of the orthorhombic phase as a deformation induced primarily by antiferroelectric displacements. A structure refinement of orthorhombic $\text{V}_{0.95}\text{Cr}_{0.05}\text{O}_2$ shows that one-half of the V ions exhibit purely antiferroelectric displacements, one-quarter purely V-V bonding, and the remaining quarter remain in the center of symmetry of a distorted interstice, as in a Jahn-Teller distortion.

Single crystals of semiconducting ferromagnetic $\text{Fe}_{1-x}\text{Cu}_x\text{Cr}_2\text{S}_4$ alloys up to 5 mm on a side have been grown by a closed-tube vapor transport technique which uses CrCl_3 as the transport agent. When the crystals are annealed in vacuum or in sulfur vapor, their lattice parameters are significantly affected by the resulting changes in the sulfur-to-metal ratio.

The effects of hydrostatic pressure on the electrical properties of n-type CdTe heavily doped with Cl, Br, Ga, or In show that the effective donor levels introduced by these impurities are associated primarily with a conduction band minimum lying above the lowest minimum at Γ ($k = 0$). The transfer of electrons between these non- Γ levels and the Γ minimum is a thermally activated process which at sufficiently low temperatures becomes too slow for equilibrium to be achieved experimentally.

III. PHYSICS OF SOLIDS

Extension of Shubnikov-de Haas measurements in $\text{Pb}_{1-x}\text{Sn}_x\text{Se}$ ($x = 0.17$ and 0.20) to high magnetic fields has allowed the observation of spin splitting. Large and isotropic g-factors ($87 \geq g \geq 48$), which depend on doping, are determined from these measurements.

Experimental measurements have been carried out for the voltage dependence of the incremental capacitance of evaporated metal Schottky barriers on p-InAs and p-PbTe. The results have been interpreted in terms of a theory which takes the inverted surface layer into account and which holds even when the band bending in the semiconductor exceeds the energy gap.

Preliminary studies of optically pumped stimulated emission from homogeneous n-PbTe platelets have been carried out, using a Q-switched CO gas laser as a pump. Although the conversion efficiency in these experiments is low ($\leq 1\%$), this system holds two promising possibilities, namely: resonant pumping near the PbTe energy gap, and stimulated spin-flip scattering.

Work on the identification of the intense 1082 cm^{-1} line in FeF_2 , previously observed by Raman scattering, has been augmented by infrared absorption measurements as well as Raman scattering in MnF_2 and MgF_2 doped with Fe^{2+} . Present evidence suggests that this line is either (a) a pair-excitation involving a crystal field state and a magnon or (b) a single ion excitation involving the exchange field and spin-orbit coupling.

A finite temperature, two-magnon Raman scattering theory, developed to describe observations in a three-dimensional antiferromagnet, has been extended to the description of the two-dimensional antiferromagnet K_2NiF_4 . The results should contain information on the persistence of short-range order above the critical temperature for the disappearance of long range order.

A study has been carried out of a permanent (at least 3 days) lens effect induced by illumination with a low power 6328 \AA laser in bulk samples of high-conductivity single crystal CdS at temperatures above 100° C . The lens is erasable by annealing at higher temperatures.

IV. MICROELECTRONICS

Several service-oriented programs have made notable progress in the past quarter as evidenced by the operating performance obtained on E-Birds, TRAPATT and gallium arsenide devices. Characteristically, however, these developmental programs are often open ended in terms of secondary specifications such as power handling capabilities, minimum noise figure and physical configuration. As a result, new phases of development often follow the initial phase of work in order to achieve greater levels of circuit performance. The degree of success achieved in these secondary program phases is based on further process refinements, control of process parameters and the over-all integration of masks, materials, processing, assembly and packaging techniques, and is limited by the uncertainties inherent in any developmental program. In those cases where similar commercial work is available for comparison, the devices fabricated here exhibit better characteristics and the over-all development time is shorter, although considerably longer than we would like.

Several developmental programs related to interconnections, assembly and fabrication, particularly the beam leaded substrates, gridded ceramic substrates and the SIMTOP process are being adopted in commercial as well as internal programs.

The development of the laser scanner for testing devices and monolithic integrated circuits is continuing. The usefulness of the system for diagnostic purposes and the testing of multichip assemblies has been established. The limitations of the system in testing MOS (metal oxide silicon) structures and LSI is currently being evaluated in terms of the defects and faults that can be seen and the problems associated with computerizing the output data.

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